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SITE Technology Capsule
Geotech Development Corporation Cold Top *Ex-Situ* Vitrification Technology

Introduction

In 1980, the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Super-fund, which is committed to protecting human health and the environment from uncontrolled hazardous waste sites. CERCLA was amended by the Super-fund Amendments and Reauthorization Act (SARA) in 1986. SARA mandates cleaning up hazardous waste sites by implementing permanent solutions and using alternative treatment technologies or resource recovery technologies to the maximum extent possible.

State and federal agencies and private organizations are exploring a growing number of innovative technologies for treating hazardous wastes. These new innovative technologies are needed to remediate the more than 1,200 sites on the National Priorities List, which involve a broad spectrum of physical, chemical, and environmental conditions requiring diverse remedial approaches.

The U.S. Environmental Protection Agency (EPA) has focused on policy, technical, and informational issues related to exploring and applying new technologies to Superfund site remediation. One EPA initiative to accelerate the development, demonstration, and use of innovative technologies for site remediation is the Superfund Innovative Technology Evaluation (SITE) Program.

EPA SITE Technology Capsules summarize the latest information available on selected innovative treatment and site remediation technologies. The Technology Capsules assist EPA remedial project managers, EPA on-scene coordinators, contractors, and other remedial managers in the evaluation of site-specific chemical and physical characteristics to determine a technology's applicability for site remediation.

This Technology Capsule provides information on the Cold Top ex-situ vitrification system, developed by Geotech Development Corporation (Geotech), of King of Prussia, Pennsylvania. Geotech has targeted vitrification of contaminated soil from chromium-contaminated sites in nor-them New Jersey as a potential application for its technology. To test the system's potential effectiveness on such chromium-contaminated soil, the Cold Top technology was demonstrated at the Geotech pilot facility in Niagara Falls, New York, using soil from two of the New Jersey chromium sites. The SITE Program evaluated the technology's performance during the demonstration.

This Technology Capsule describes the Cold Top technology and summarizes results based on the

SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

Cold Top SITE demonstration objectives. This capsule includes the following information:

- Abstract
- Technology description
- Technology applicability
- Technology limitations
- Process residuals
- Site requirements
- Performance data
- Technology status
- Sources of further information

Abstract

A SITE technology demonstration was conducted in February and March 1997 to evaluate the potential applicability and effectiveness of the Geotech Cold Top *ex-situ* vitrification technology on chromium-contaminated soils. The demonstration was conducted using the vitrification furnace at Geotech's pilot plant in Niagara Falls, New York. Chromium-contaminated soil from two state Super-fund sites in the Jersey City, New Jersey, area was collected, crushed, sieved, dried, mixed with carbon and sand, and shipped to the Geotech pilot plant. The SITE demonstration consisted of one vitrification test run on soil from each site. During each test, solid and gas samples were collected from various locations in the Cold Top system and analyzed for several chemical and physical parameters. In addition, process monitoring data were recorded. During the demonstration, the Cold Top system treated approximately 10,000 pounds of Resource Conservation and Recovery Act (RCRA) characteristic-hazardous soil contaminated with trivalent and hexavalent chromium and other metals.

One primary and five secondary objectives were identified for the SITE demonstration. The primary objective was to develop test data to evaluate whether the waste and product streams from the Cold Top vitrification system pilot plant were capable of meeting the EPA RCRA definitions of a nonhazardous waste, based on the stream's leachable chromium content. Secondary objectives were to determine the following: (1) partitioning of total and hexavalent chromium from the contaminated soil into the various waste and product streams; (2) the ability of the vitrified product to meet New Jersey Department of Environmental Protection (NJDEP) environmental and engineering criteria for use as fill material (such as road construction aggregate); (3) the system's ability to meet applicable compliance regulations for controlled air emissions of dioxins, furans, trace metals, particulate, and hydrogen chloride; **(4)** the uncontrolled air emissions of the oxides of nitrogen, sulfur dioxide, and carbon monoxide from the vitrification unit; and (5) the projected operating costs of the technology per ton of soil.

Demonstration results showed that the Cold Top system vitrified chromium-contaminated soil from the two New Jersey sites, yielding a product meeting the RCRA toxicity characteristic leaching procedure (TCLP) standards. From soil excavated at one of the New Jersey sites, the system yielded a potentially recyclable metallic product, referred to as "ferrofurnace bottoms," that also met the RCRA TCLP chromium standard. Demonstration results also showed that the total chromium content of the vitrified products did not differ significantly from that of the untreated soils, but that the baghouse dust from soils from both sites were higher in chromium content than the untreated soils. The baghouse dust is composed of small-sized particulate produced when untreated soil is added to the Cold Top furnace and then drawn through the air pollution control system by its vacuum. Hexavalent chromium concentrations in the untreated soil were generally not detected (reduced at least two to three orders of magnitude) in the vitrified product and ferrofurnace bottoms. The hexavalent chromium concentration in the baghouse dust was approximately the same as that in the untreated soil.

Comparison of metal concentrations in the vitrified product to NJDEP interim soil cleanup standards indicates that antimony, beryllium, cadmium, vanadium, and hexavalent chromium met these standards, while total chromium and nickel did not. Results of emissions modeling indicate that the concentrations of metals in stack emissions depend on the characteristics of the soil, the air pollution control system, and the detection limits of the various analytes. Emissions of dioxins, particulate, oxides of nitrogen, sulfur dioxide, carbon monoxide, and hydrogen chloride were all below the appropriate New York limits, based on appropriate measurement and calculation procedures.

Analysis of operating costs indicates that Cold Top treatment of chromium-contaminated soil, similar, to that treated during the SITE demonstration,' is estimated to cost from $77 to $207 per ton, depending on disposal costs and potential credits for sale of the vitrified product.

The Cold Top technology evaluation, described in detail in an Innovative Technology Evaluation Report, was based on the nine decision-making criteria used in the Super-fund feasibility study process. Results of the evaluation are summarized in Table 1.

Technology Description

The Geotech Cold Top technology is an *ex-situ* vitrification process designed to transform metal-contaminated soils into a nonleachable product. The primary component of the technology is a water-cooled, double-walled, steel vessel or furnace with submerged-electrode resistance heating. The vessel is designed to pour from the bottom while being fed either manually or automatically from the top. Geotech has developed a procedure of maintaining electrical balance such that the feed, melt, and pour processes occur at the same rates. Figure 1 is a schematic depiction of the furnace and associated equipment.

Geotech claims that this technology converts quantities of contaminated soil from a large number of particles into an essentially monolithic, vitrified mass. According to Geotech, vitrification will transform the physical state of contaminated soil from assorted crystalline matrices to a glassy, amorphous solid state comprised of interlaced polymeric chains. These chains typically consist of alternating oxygen and silicon atoms. It is expected that chromium can readily substitute for silicon in the chains. According to Geotech, such chromium should be immobile to leaching by aqueous solvents and, therefore, biologically unavailable and nontoxic. Geotech has targeted vitrification of contaminated soil from chromium-contaminated sites in Northern New Jersey as a potential application for the system. To test its potential applicability and effectiveness on such chromium-contaminated soil, the Cold Top technology was demonstrated at the Geotech pilot facility in Niagara Falls using soil from two northern New Jersey sites.

According to Geotech, the furnace and associated equipment are capable of attaining melting temperatures of up to 5,200 °F. The technology has been used to vitrify chromium-contaminated soil, municipal solid waste incinerator ash, fly ash, asbestos and asbestos-containing materials, ceramic minerals, and a range of other materials, including soils contaminated with metals such as lead and cadmium. The vitrified product can be formed into glassy blocks of up to 300 pounds or as granular, nonporous solids of 3/8 inch or smaller. The vitrified product has potential economic value as shore erosion block, roadbed fill, aggregate for concrete or asphalt, or other uses where a high-density, solid material is needed. The product can also be spun into mineral or ceramic fiber, that may have economic value as insulation, wall board, industrial furnace linings, and ceramic fiber.

Geotech currently operates a 50-ton-per-day Cold Top vitrification pilot plant in Niagara Falls, New York. This facility has been used for over 38 research and customer demonstrations, including the SITE demonstration. Materials fused in this plant range from high purity zirconia and magnesite, requiring fusion temperatures in excess of 5,000 °F, to contaminated soils that melt at 1,800 °F. Geotech has also built or assisted with the construction or upgrading of five operating vitrification plants and tentatively plans to build a commercial Cold Top vitrification facility within 50 miles of the northern New Jersey sites. The planned capacity of this facility is 300 tons per day. Geotech is also evaluating the building of a transportable system.

Technology Applicability

The Cold Top process can be applied to soils, sludge ashes, and other solid materials contaminated with chromium, lead, cadmium, other metals, and asbestos after the material to be treated has been prepared, such as by drying, crushing, and amending, as necessary. Laboratory- and pilot-scale Cold Top systems have been used to treat solid materials contaminated with trivalent and hexavalent chromium, municipal solid waste residue, and asbestos and asbestos-containing materials. Other materials that have been vitrified include both granite and blast furnace slag to make mineral wool insulation, alumina and silica to make mineral wool fiber and vacuum cast shapes; coal fly ash and incinerated sewage-sludge residue to form glass fiber; and oil ash residue containing metals to form high-strength glass blocks.

Technology Limitations

Geotech claims the Cold Top *ex-situ* vitrification process can be used to vitrify any solid material with a few limitations. Vitrification requires a significant amount of energy; therefore, the technology is usually limited to dried solids that are relatively low in total organic content. The energy required to heat and

Table 1. Feasibility Study Evaluation Criteria for the Geotech Technology

Criterion	Geotech Technoloav Performance
1 Overall Protection of Human Health and the Environment	The Cold Top process fuses hazardous inorganic constituents into a noncrystalline, glass-like product. Air emissions are reduced by using an air pollution control system (APCS).
2 Compliance with Federal ARARs	Compliance with chemical-specificapplicable or relevant and appropriate requirements (ARAR) depends on the treatment efficiency of the vitrification system and the chemical constituents of the waste. Compliance with chemical-, location-, and action-specific ARARs must be determined on a site-specific basis. For most sites, the following environmental regulations will be applicable to Cold Top operations: Comprehensive Environmental Response, Compensation, and Liability Act, Resource Conservation and Recovery Act (RCRA), the Clean Air Act, the Clean Water Act, the Occupational Safety and Health Act, and the Toxic Substances Control Act.
3 Long-Term Effectiveness and Permanence	As the vitrified products met RCRA Toxicity Characteristic Leaching Procedure requirements, these fused wastes were considered to be permanently treated. Treatment residuals from the APCS can be recycled through the system, and the vitrified product and the ferrofurnace bottoms may be recycled or may require proper off-site disposal.
4 Reduction of Toxicity, Mobility, or Volume Through Treatment	Vitrification reduces the mobility of the waste feed by fusing hazardous inorganic constituents into a high-density, noncrystalline, glass-like product. Toxicity is also reduced by the chemical reduction of hexavalent chromium to less toxic species, such as trivalent chromium.
5 Short-Term Effectiveness	Short-term risks to workers, the community, and the environment are present during waste-handling activities and from potential exposure to air emissions. Adverse impacts from both activities can be mitigated with proper safety and waste-handling procedures and air pollution system controls.
6 Implementability	The Cold Top system vitrifies a wide variety of materials. Geotech plans to establish a full-scale fixed facility in the northern New Jersey area. Currently, Geotech does not operate a transportable system, so only transportation of the waste feed needs to be evaluated for this criterion.
7 cost	Costs for treatment by the Cold Top technology depend on waste- and location-specific factors such as the volume of material to be treated, physical properties of the material to be treated, transportation costs, electricity costs. and economic value or cost to dispose of the vitrified product and ferrofurnace bottoms. For the treatment scenarios evaluated in the economic analysis contained in the Innovative Technology Evaluation Report, costs ranged from $77 to $207 per ton.
8 State Acceptance	State acceptance of the full-scale, fixed Cold Top facility is likely to be favorable.
9 Community Acceptance	The minimal short-term risks presented to the community, along with the permanent fusing of hazardous waste constituents in the waste producing a potentially usable product, should increase the likelihood of community acceptance of this technology. Additionally, as treatment by this technology takes place off site, acceptance by the community where the waste is removed should be favorable.

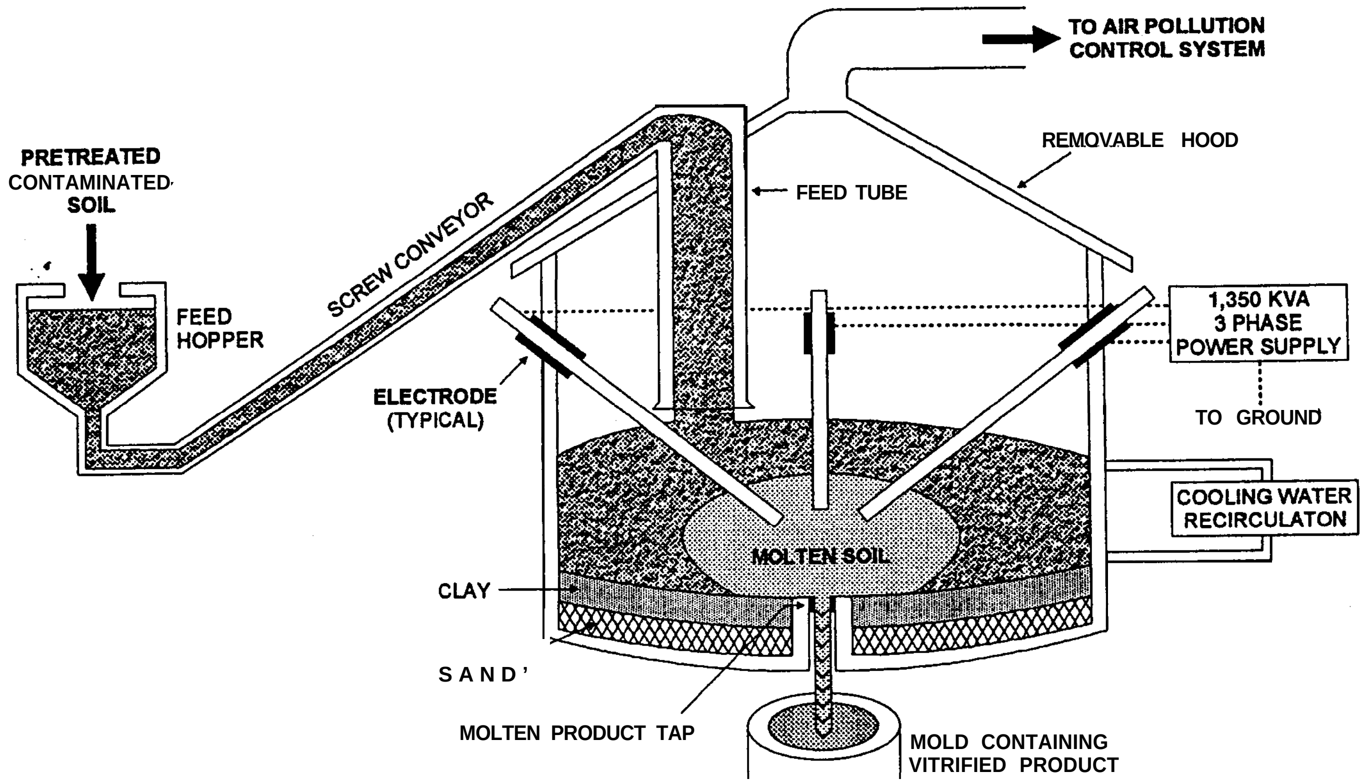

Figure 1. A Schematic Depiction of the Furnace and Associated Equipment

evaporate water or organics would raise the cost of the technology, and it would produce such a large amount of steam and organic vapors, that an off-gas treatment system would need to be configured to handle this material. The ideal water and organic content of untreated waste material should each be less than 5 percent. If the water content of the untreated waste is greater than 5 percent, the waste will require drying, possibly using heat scavenged from the vitrified material. If the organic content of the untreated waste is greater than 5 percent, it may be necessary to blend that material with less contaminated material. Vitrification occurs most efficiently, producing a better glass product, when the waste particle size is small; therefore, waste material should be sized to a diameter of 0.12 to 0.25 inch by sieving, crushing, or grinding.

Certain waste materials require the addition of small amounts of carbon to facilitate reduction of metal oxides, such as ferric oxide to elemental iron, in the furnace. Sand also may be added to the waste material prior to vitrification to facilitate vitrification and improve the physical strength and characteristics of the vitrified product. These additives must be mixed with the untreated waste material prior to vitrification.

Process Residuals

During the SITE demonstration, the Cold Top vitrification process produced several types of residual material: vitrified product, baghouse dust, and stack emissions. The vitrified product is expected to be nonleaching and saleable as sand-sized material or larger aggregate. The baghouse dust can be recycled back through the vitrification process. The stack emissions are controlled with various air pollution control devices.

Certain types of untreated wastes may also produce a metallic product referred to as ferrofurnace bottoms. This material is a potentially saleable product, as it is usually composed of iron and other metals. Depending on the off-gas treatment-system configuration, scrubber water also may be produced. This water may have low levels of contamination and can be recycled or possibly treated and disposed of through a publicly owned treatment works. If a cyclone separator or electrostatic precipitator is used, the particulate material collected from these air pollution control devices can be recycled through the vitrification furnace. Although not evaluated in this demonstration, when the vitrified product is quickly quenched in water, producing a sand, the cooling water is also a residual. The cooling water may have low levels of contamination that need to be evaluated. This water can be recycled thru the process or can be tested prior to treatment and disposal through a publicly owned treatment works.

Site Requirements

Currently, the Geotech Cold Top pilot-plant operates in Niagara Falls, New York, and a full-scale facility is planned for the northern New Jersey or southeastern New York area. A transportable unit is currently unavailable. Therefore, the only site requirements to implement the technology are those typical of soil excavation activities, such as obtaining the proper permits, equipment, and access to excavate the contaminated soil for transport to an off-site Cold Top vitrification facility.

Performance Data

The performance of the Cold Top ex-situ vitrification system was evaluated at the Geotech pilot-plant in February and March 1997. Chromium-contaminated soil collected from two sites, NJDEP Site 130 and Liberty State Park, in Jersey City, New Jersey, was used for the test. To achieve the demonstration objectives, one demonstration test run was performed for each of the two soils. The untreated soils and treated products were analyzed in triplicate. Stack gases were collected and analyzed for both of the test runs. The Cold Top system was operated at an average feed rate of 2,500 pounds per hour for the first batch of soil and 3,000 pounds per hour for the second.

The following key findings of the Cold Top technology SITE demonstration are listed in the following paragraphs. Readers desiring more detail are referred to the Cold Top Innovative Technology Evaluation Report.

RCRA TCLP Chromium Standard

The Cold Top technology vitrified chromium-contaminated soil from two New Jersey sites, producing a product meeting the RCRA TCLP total chromium standard (see Tables 2 and 3). Vitrification of soil from one of the two sites also produced ferrofurnace bottoms, a potentially recyclable metallic product, that also met the RCRA TCLP total chromium standard.

Chromium Partitioning

With the exception of the baghouse dust and the ferrofurnace bottoms sample, the total chromium content of the vitrified product did not differ significantly from that of the untreated soil. The concentration of total chromium in the vitrification baghouse dust and ferrofurnace bottoms samples were approximately two and five times greater, respectively, than those found in the untreated soil. These data are summarized in Tables 2 and 3.

Hexavalent chromium was not detected in the ferrofurnace bottoms samples and was only detected in one of six vitrified product samples. The hexavalent chromium concentrations ranged from one-half to approximately the same in the vitrification baghouse dust as in the untreated soil. The

Table 2. Average Contaminant Concentrations in SITE Demonstration Samples from Site 130

Contaminant	Feed Soil	Baghouse Dust	Ferrofurnace Bottoms	Vitrified **Product**
Total Hexavalent Chromium (mg/kg)	1,900	1,800	--[1]	co.41 [2]
Total Chromium (mg/kg)	5,100	11,000	--[1]	5,530
TCLP Chromium (mg/L)[3]	58	23.7	--[1]	0.31

Notes:

1. Ferrofurnace bottoms were not produced from the vitrification of soil from Site 130.
2. No hexavalent chromium was detected. The value reported is the highest detection limit for the three samples analyzed
3. The RCRA TCLP standard for chromium is 5.0 mg/L.

mg/kg milligrams per kilogram
mg/L milligrams per liter

Table 3. Average Contaminant Concentrations in SITE Demonstration Samples from Liberty State Park

Contaminant	Feed Soil	Baghouse Dust	Ferrofurnace Bottoms	Vitrified Product
Total Hexavalent Chromium (mg/kg)	897	360	<4.0	1.8 to<0.39[1]
Total Chromium (mg/kg)	6,900	16,000	35,900	10,300
TCLP Chromium (mg/L)[2]	29.3	11.3	2.4	1.04

Notes:

1. Hexavalent chromium was detected in one of three samples. The range of values reported is the concentration in the sample where it was detected and the lowest detection limit.
2. The RCRA TCLP standard for chromium is 5.0 mg/L.

baghouse dust was presumed to be mainly fine-sized, untreated soil that was generated when soil was added to the vitrification furnace and then carried through the air pollution control system.

Cost

Cold Top treatment of chromium-contaminated soil, similar to that treated during the SITE demonstration, is estimated to cost from $77 to $207 per ton, depending on disposal costs and potential credits for the vitrified product. The three scenarios evaluated included (1) use of the vitrified product as aggregate, (2) backfilling of the aggregate on site, and (3) landfilling of the aggregate. Costs for these three scenarios were $77, $97, and $207 per ton, respectively. Because of the uncertainty of their formation, potential credits for ferrofurnace bottoms was not considered in this economic analysis.

NJDEP Interim Cleanup Standards

Comparison of metal concentrations in the vitrified product to the NJDEP interim cleanup standards indicated that the vitrified product met the interim standard for antimony, beryllium, cadmium, vanadium, and hexavalent chromium, but did not for nickel and total chromium.

Stack Emissions

Although the Cold Top technology is not an incineration technology, the stack emissions from the demonstration were compared to Subpart 0 incinerator regulations, and the results were mixed. The data collected during the SITE demonstration were input into complex modeling calculations supplied by New York State. The modeling required site- and waste-specific analyses to assess the impact of the Cold Top stack emissions. Results of emissions modeling indicate that the concentrations of metals in stack emissions depend on the characteristics of the soil, the air pollution control system, and the detection limits of the various analytes. Emissions of dioxins, particulate, oxides of nitrogen, sulfur dioxide, carbon monoxide, and hydrogen chloride were all below the appropriate New York limits, based on appropriate measurement and calculation procedures.

Technology Status

Geotech owns a 50-ton-per-day Cold Top vitrification pilot-plant in Niagara Falls, New York. This facility was used for over 38 research and customer demonstrations, including the SITE demonstration. Geotech claims that this plant is capable of melting any mineral or combination of minerals present in a relatively dry condition.

Geotech has built or assisted with the construction or upgrading of five operating vitrification plants. Plants are located in (1) Teplice, Czechoslovakia, where the capacity exists to produce 800 pounds per hour of alumina silica ceramic fiber from the vitrified material; (2) Atella, Italy, where approximately the same capacity exists to produce ceramic fiber; (3) Lorete, France, where Geotech supplied molten stream control, high speed spinning, and fiber collection equipment; (4) Nagano, Japan, where Geotech furnished a melting furnace, electrical controls, high speed spinning equipment, and fiber collectidn equipment for a plant that produces ceramic fibers; and (5) Nagoya, Japan, where Geotech installed mineral fusion and fiber formation equipment in a plant designed to vitrify a wide variety of solid mineral waste materials, including clamshell residue, sludge-ash residue, coal-ash residue, and municipal solid waste ash.

Geotech has tentative plans to build a commercial Cold Top vitrification facility within 50 miles of the northern New Jersey sites. The planned capacity of this facility is 300 tons per day. The facility will be designed to receive, dry, vitrify, and dispose of the vitrified product from the chromium sites and municipal solid waste incinerators, as well as other producers of hazardous and nonhazardous waste.

Disclaimer

The data and conclusions presented in this Technology Capsule have not been reviewed by the EPA Quality Assurance Office.

Sources of Further Information

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